Radar and Radio Range Simulation Using Fiber Optic Delay Lines

By Jerry Lomurno and Joe Mazzochette

Fiber Optic Delay Line systems (FODL) are used in test and development laboratories to eliminate outdoor range testing of radio and radar systems. Outdoor range testing is costly, complex, and time-consuming. The key advantage of FODL system technology is the repeatability of the simulation. FODL eliminates environmental anomalies such as weather and other interfering transmissions. Planning and preparation costs of setting up range tests alone are all too often lost due to very minor unforeseen operational and system errors. Thousands of dollars, and hundreds of hours, can be saved using FODL in place of, or together with, reduced range testing.

The main advantages of FODL systems are:

- Dramatic savings in test cost and time, keeping projects on time and under budget
- Accuracy, repeatability, and reliability
- In-lab testing up to 150 miles including “range formula” level set
- Designers can perform device under test (DUT) optimization in a lab
- Brings testing into 21st century by combining optics with microwave technology

Delay Line Core Technology

Eastern OptX’s core technology enables the conversion of microwave signals to optical signals (E/O), time delaying the signal, then reconverting the light back to original microwave signal (O/E). This method results in superior fidelity over traditional time delay methods. Products using this technology include radar target simulation, radar altimeter testing, channel simulation (air interface), and multipath creation. This approach allows users to test “in the lab”—resulting in dramatically lower costs and higher efficiencies than available with outdoor test ranges. Systems are available with fixed or programmable delays ranging from a few nanoseconds (2 feet) to hundreds of microseconds (150 miles), input RF frequencies of up to 40 GHz, internal attenuation control accurately simulates free space propagation loss. All features can be touch-screen controlled using an intuitive graphical user interface. (Fig. 1)

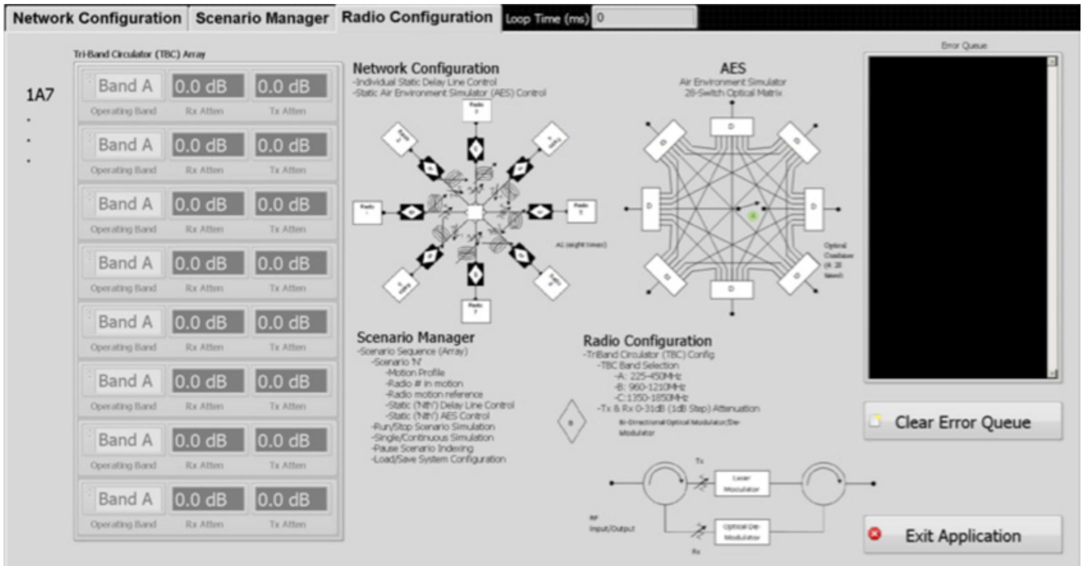

Figure 1: All features of the Eastern OptX Series 7000 can be controlled with a touch-screen using an intuitive graphical user interface as shown here.

Radar Testing with Fiber Optic Delay Lines (FODL)

In this paper we will show how to make use of a relatively new technology—fiber optic microwave delay lines or FODL—to finally enable the measurement of key radar parameters. These tests include radar range accuracy, multipath effects, moving targets, and minimum discernible signal (Rx sensitivity)—all in a laboratory.

"Outdoor testing for range accuracy is expensive, time-consuming, and in many cases not as accurate as you might desire..."

Testing 95 percent of a radar system has always been an easy and interesting task. An abundance of test equipment has been available since the mid 1940s to do the job, including spectrum analyzers, power meters, signal generators, oscilloscopes, etc. Pulse width, frequency, rise/fall time, pulse profile, even FM deviation of chirp signals can easily be measured with fairly simple suite of test equipment.

Radar Range Accuracy

However, "live" testing for range accuracy is expensive, time consuming, and in many cases, not as accurate as you might desire—not to mention the community's concern about radiating high power microwaves over the local population. To test a radar range, usually an airplane is sent out that squawks its position continuously while the tester monitors the radar's range indicator for accuracy. Radar return signal quality is diminished by weather conditions, multipath interferences, as well as other transmitting signals nearby.

Shorter range radars can use fixed targets such as putting a radar reflector on bore site towers, existing structures such as tall buildings, or even mountains. Again, the neighborhood and environment represent certain impediments. In fact, many modern types of radars transmit signals with complex phase modulation so any wobble of a bore site tower makes the reflections useless.

Receiver Sensitivity, MDS (Minimum Discernible Signal)

Since a radar system processes everything that bounces back into the receiver, signals from buildings, trees, ground reflections, and even water (ground and sea clutter) show up as noise (Fig. 2). In order to accurately measure the minimum discernible signal (MDS), the test engineer needs the target return to be out beyond the clutter. Until recently, a delaying pulse generator and signal generator set to a radar's transmit frequency could adequately replicate this scenario (Fig. 2). Again, now that these radars use complex modulation and/or frequency hopping on the TX pulse, the pulse/signal generator becomes useless.

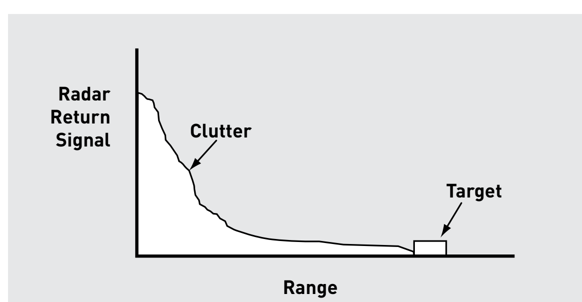

Figure 2: A typical radar return display showing why a target must be out beyond clutter returns in order to measure MDS (minimum discernible signal level).

Digital Radio Design, Qualification, and Interoperability

Today's high technology digital radios require all of the tests and simulations mentioned above. In addition, they also require extensive field testing for interoperability, rejection of interferers, and in most cases, position location algorithm verification. Eastern OptX has developed FODL products that accommodate up to eight radios operating in full duplex mode. An innovative operator GUI makes use of mapping graphics, allowing the operator to position each radio via drop and drag. The system is scalable when more than eight radios need to be tested.

> **"Eastern OptX has developed FODL products that accommodate up to 8 radios operating in full duplex mode"**

Benefits of utilizing FODL for radio testing include:

- Reduced test preparation time and cost
- Reducing expensive, time-consuming field testing
- Increased accuracy and repeatability
- Broad instantaneous bandwidth
- Protocol agnostic
- Nothing is radiated
  - Secure—no sensitive protocols are transmitted to outside world
  - No cumbersome FCC approvals required
  - No safety hazard to community

Fiber Optic Delay Lines Offer Superior Performance

Delay line technology developed by Eastern OptX uses optical signals offering superior performance over competing techniques (Fig. 3). The radar's transmit signal is used to modulate a light source, which is then connected to a proprietary-wound optical fiber coil. The coil length is selected to produce a specific time delay. The output of the fiber terminates into an optical receiver that then demodulates the signal, faithfully reproducing the original electrical waveform.

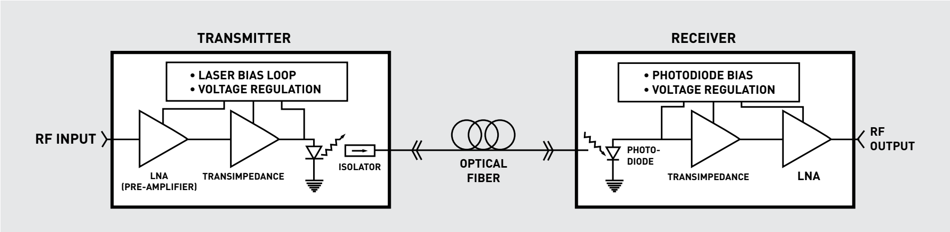

Figure 3: Block diagram of Eastern OptX unidirectional FODL. For bidirectional systems F/O circulators are incorporated along with two light sources set at different wavelengths.

Fiber-based delay lines offer greatly reduced insertion loss and dramatically improved signal quality. Fiber-based delay lines have a constant delay versus frequency, are immune to vibration, and are largely resistant to electromagnetic interference. Furthermore, fiber delays do not radiate energy that may interfere with the operation of other electrical devices or allow unauthorized detection.

Since fiber is athermal, the fiber optic approach does not require complex thermal control. Finally, the Eastern OptX fiber optic system is smaller, lighter, and lower loss than the coaxial transmission line approach. For example, a 1 km fiber optic delay (5 μs) will produce less than

0.04 db of loss, weigh less than 0.45 pounds, and require a spool that is less than 3.5 inches in diameter and less than 2.5 inches tall.

Using optical switches, multiple delay lines may be configured in parallel or serial groupings. These configurations provide either low loss fixed delays or a binary summation of multiple delays which allow the user to change the total delay in small step sizes. **Figures 4 and 5** show block diagrams of the two approaches. A hybrid of both configurations is also possible.

Fiber-based delay lines can deliver superior performance, higher reliability, reduced manufacturing costs, reduced size, reduced power consumption, EMI/EMC/vibration immunity, and longer life cycles. Fiber-based delay lines are a much-needed test and simulation tool for radar systems of the future and for refurbishment of existing aging systems.

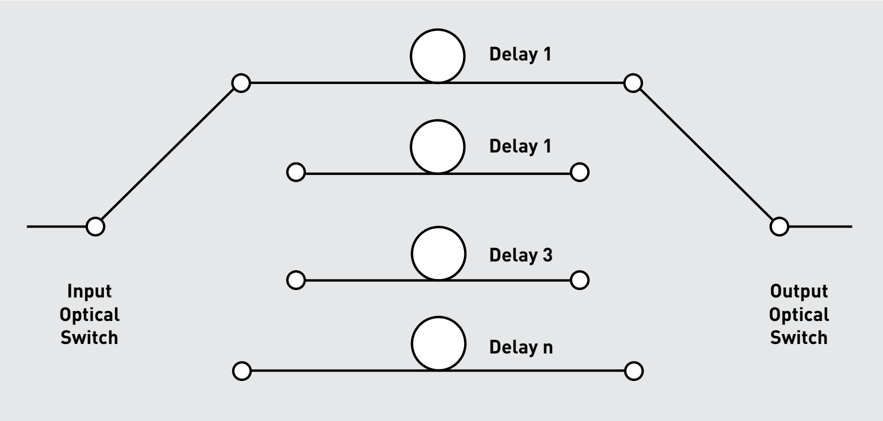

Figure 4

Fiber optic delay lines are also available with programmable attenuation set to "range formula", Doppler shift, full duplex for testing transponders, radar repeater systems with built-in GPS position reporting, ability to insert interfering signals, and multipath options with variable range and amplitude.

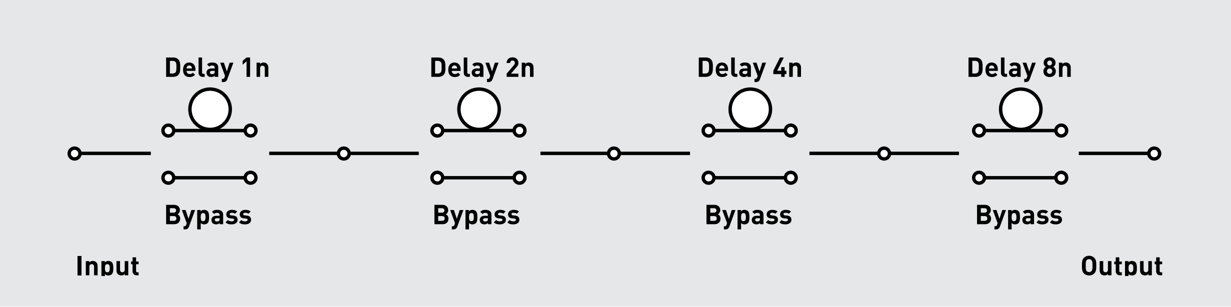

Figure 5

Eastern OptX Delay Lines
A History of Reliability for RF and Microwave Applications

In 1998, Eastern OptX began designing and developing fiber optic delay lines for the RF and microwave communities. At that time, we saw that the inherent low loss of fiber optic cable made it possible to offer delay lines for radar target simulation.

Since then, Eastern OptX's microwave delay line technology has found applications in electronic warfare (EW), electronic counter-measures (ECM), electronic counter-countermeasures (ECCM), altimeter calibration, radio range emulation, and even some multi-path fading applications.

Products offered by Eastern OptX range from a single delay of RF signals up to 3 GHz, through 8 discreet GPIB and Ethernet programmable delays for signals above 18 GHz. We have delivered systems with time delays in excess of 1,000 µs (→80 radar miles).

With a stellar record of operational performance in the field, Eastern OptX's customers have enjoyed continuous operation with virtually no down time. With tens of thousands of operational hours in a variety of environmental conditions, Eastern OptX systems are proven to be robust and reliable. Some systems have been in continuous service for more than 10 years.

Our systems are designed by a team of skilled engineers with decades of experience working in the aerospace and defense industries. Expertise in RF and microwave, optical, mechanical, electrical, and software engineering are employed to produce these rugged systems. Using the latest CAD and simulation software, Eastern OptX can produce optimized designs to quickly meet our customers' requirements. Custom software is incorporated in many systems that may be tailored for each application.

The Eastern OptX team skill set not only includes the required technical competencies, but also a deep understanding of customer applications and performance requirements. This combination allows us to guide our customers through the design process. We quickly develop and deliver systems that perform as required the first time, saving costly program delays and re-work.

Eastern OptX systems are manufactured, tested, and calibrated in a state-of-the-art facility in New Jersey, compliant with the following certifications and registrations:

- ISO-9001
- NHB 5300(1C)Ð
- MIL-I-45208A

We use the latest test and measurement systems in the manufacture, alignment, and verification of our products. Working with our customers, we develop systems with user-friendly controls, software, and interfaces. These products are lightweight with bench top, rack-mount, and portable versions available.

Please contact us to learn more about how to save time and money for your radar and radio applications. Eastern OptX is a veteran-owned business.

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